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(54) **ACCOMMODATING INTRAOCULAR LENS**

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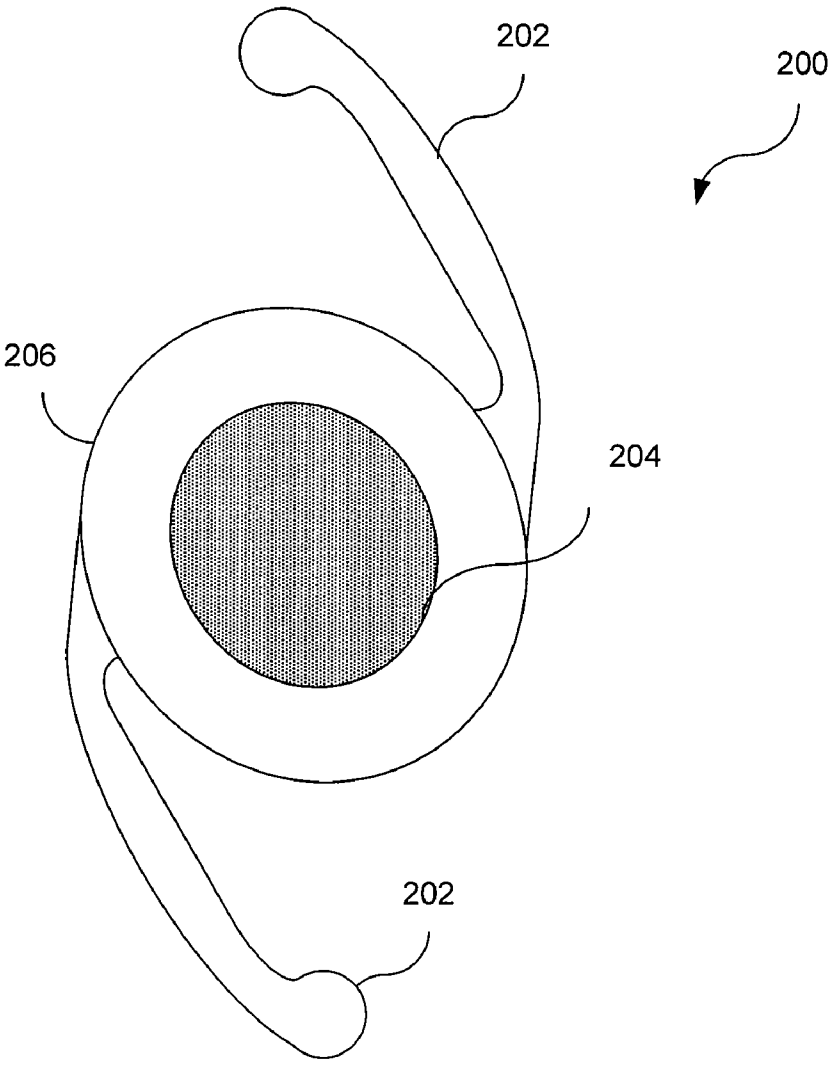
(57) **ABSTRACT**

An improved multifocal design for an ocular implant is provided. This ocular implant can include an accommodating intraocular lens (IOL) and a number of haptics. The accommodating IOL includes a liquid suspended between two optically transparent plates or membranes to form a pressure lens that passes optical energy. The haptics mechanically couple to the IOL in order to position and secure the IOL within the eye. The IOL achieves accommodation by using the eye's ciliary muscles to vary the surface curvature of the liquid. The liquid may have a high surface tension and be surrounded by phobic liquid. Pressure from the ciliary muscles causes fluid to be added from or withdrawn to a reservoir. Increasing/decreasing the internal pressure of the liquid changes the angle (curvature) of the surface thus changing the optical properties of the lens. When the pressure is released the liquid returns to the reservoir. The whole system may be sealed off from the interior of the eye by a membrane/transparent lens.



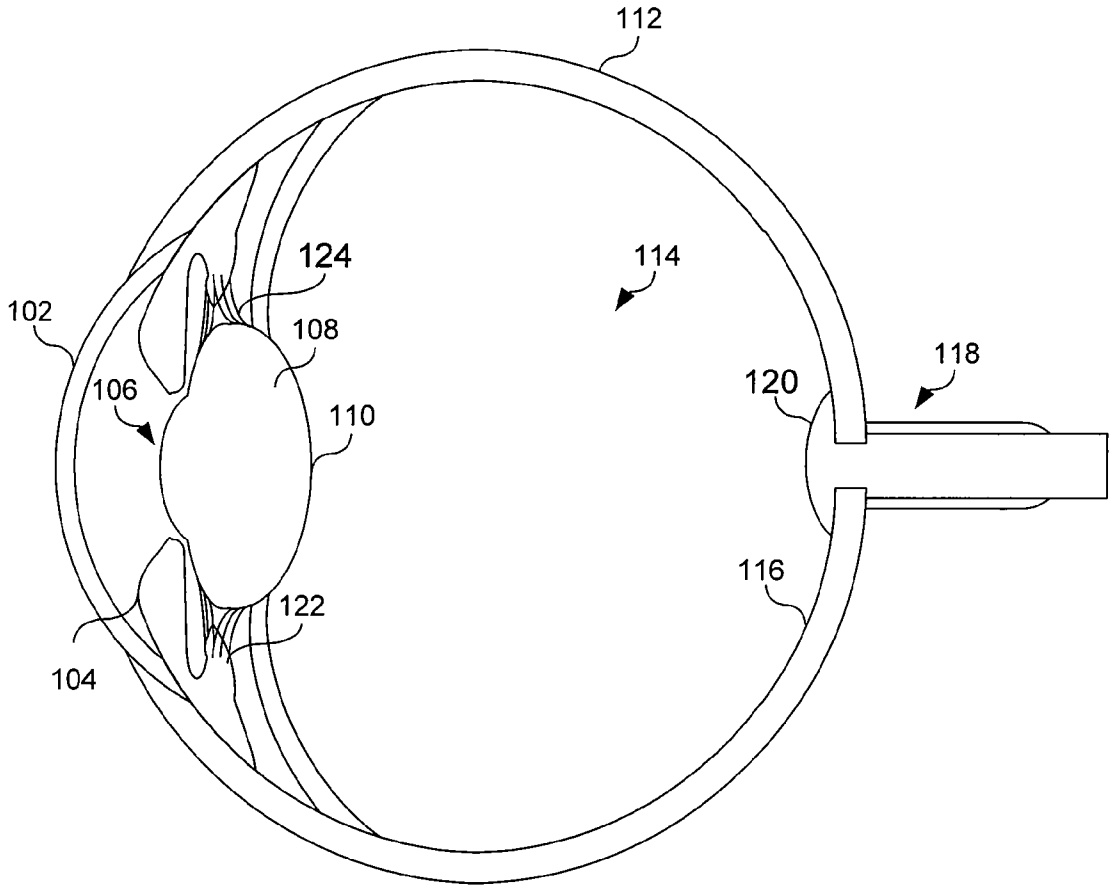


FIG. 1

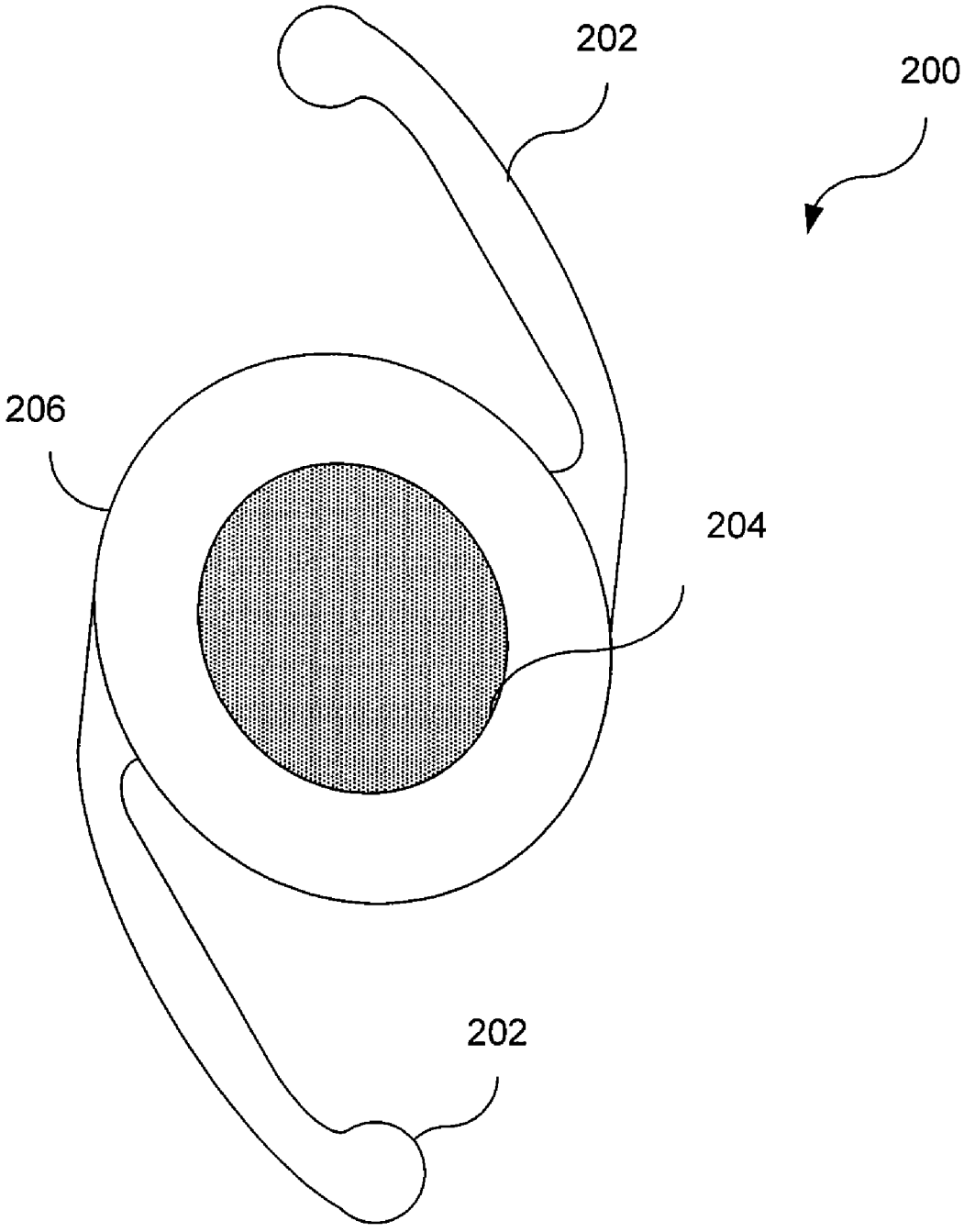


FIG. 2

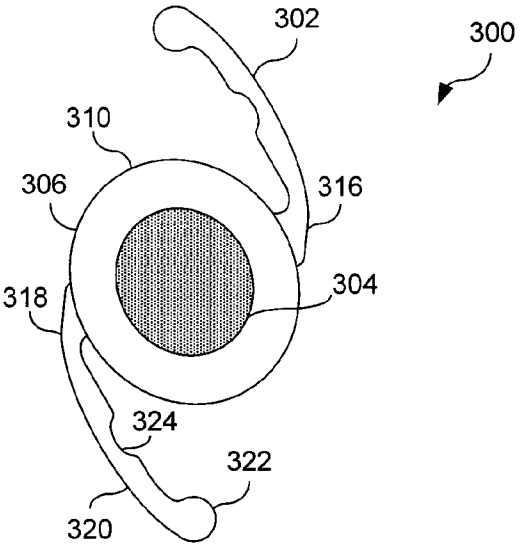


FIG. 3A

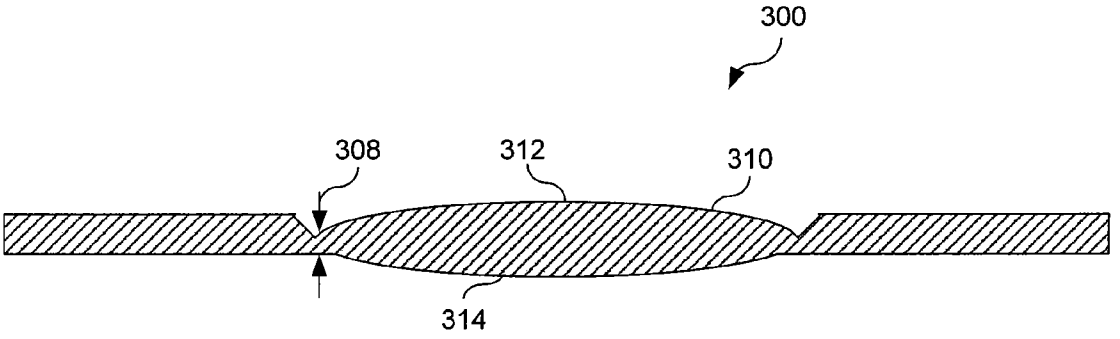


FIG. 3B

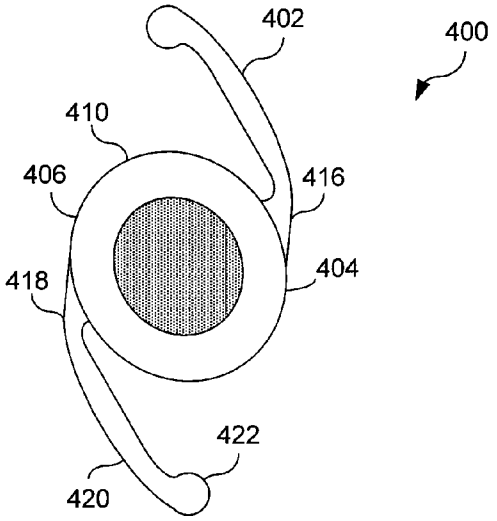


FIG. 4A

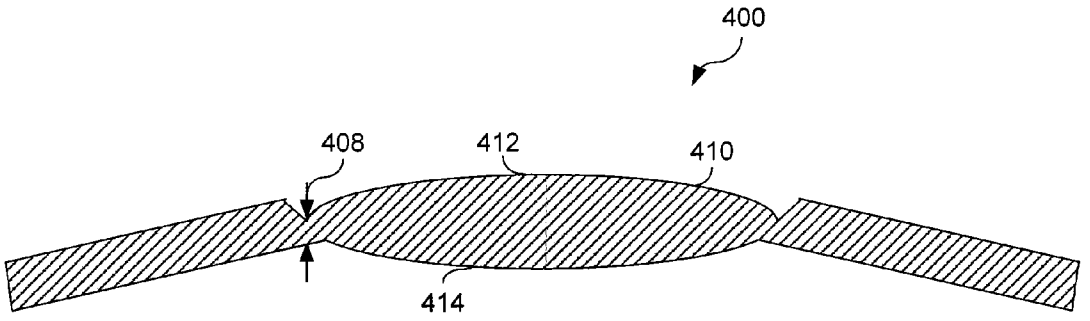


FIG. 4B

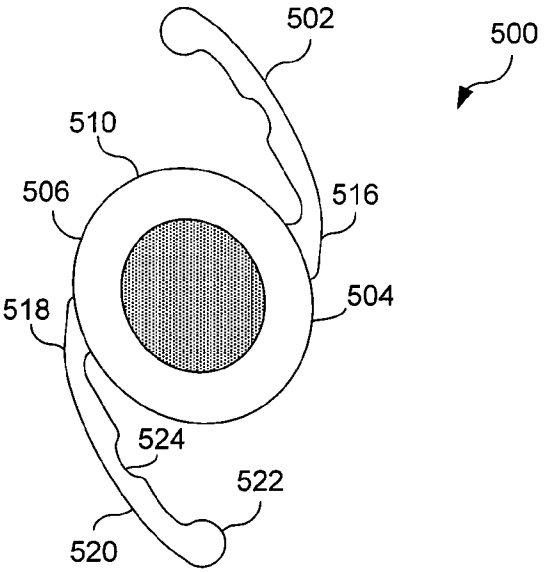


FIG. 5A

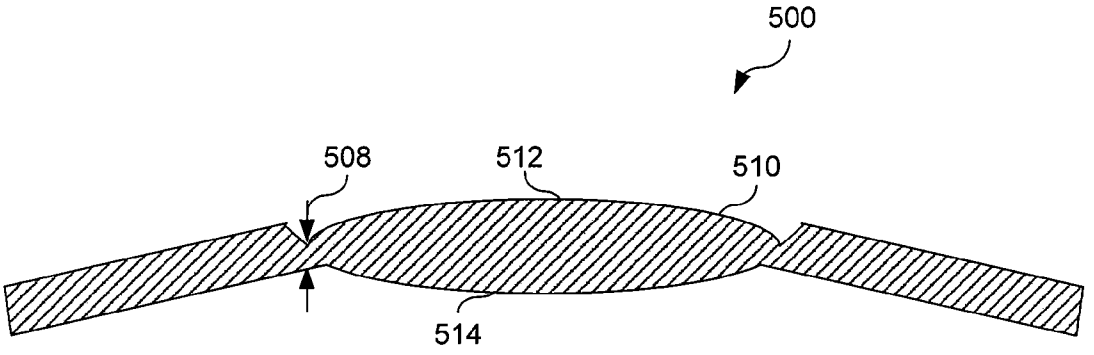


FIG. 5B

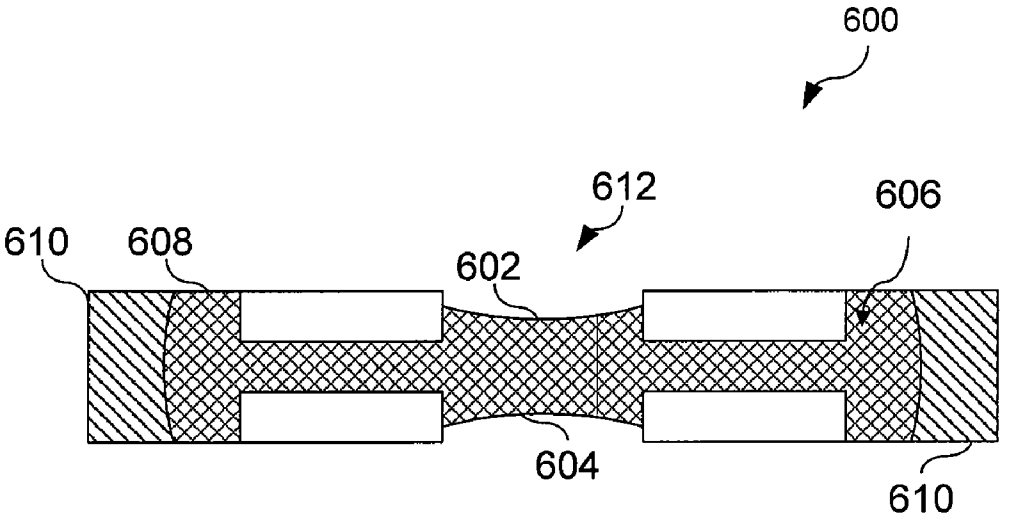


FIG. 6A

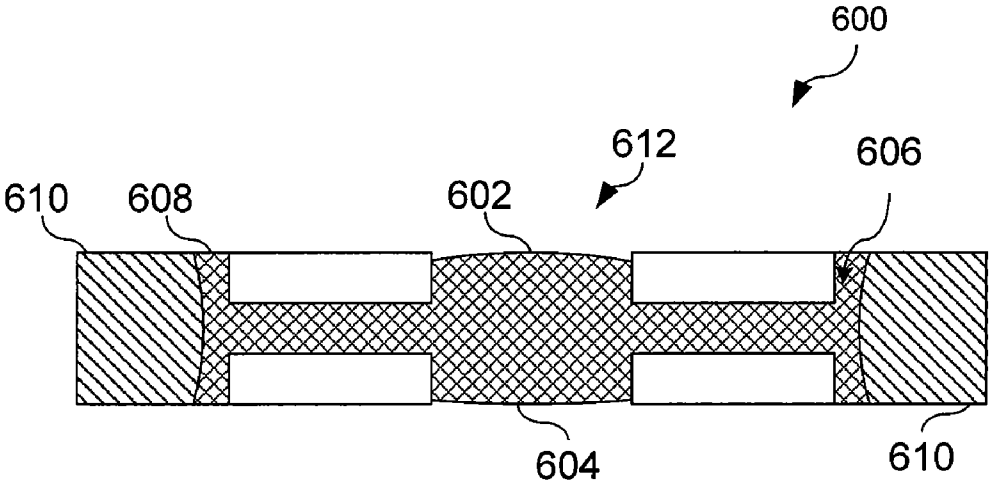


FIG. 6B

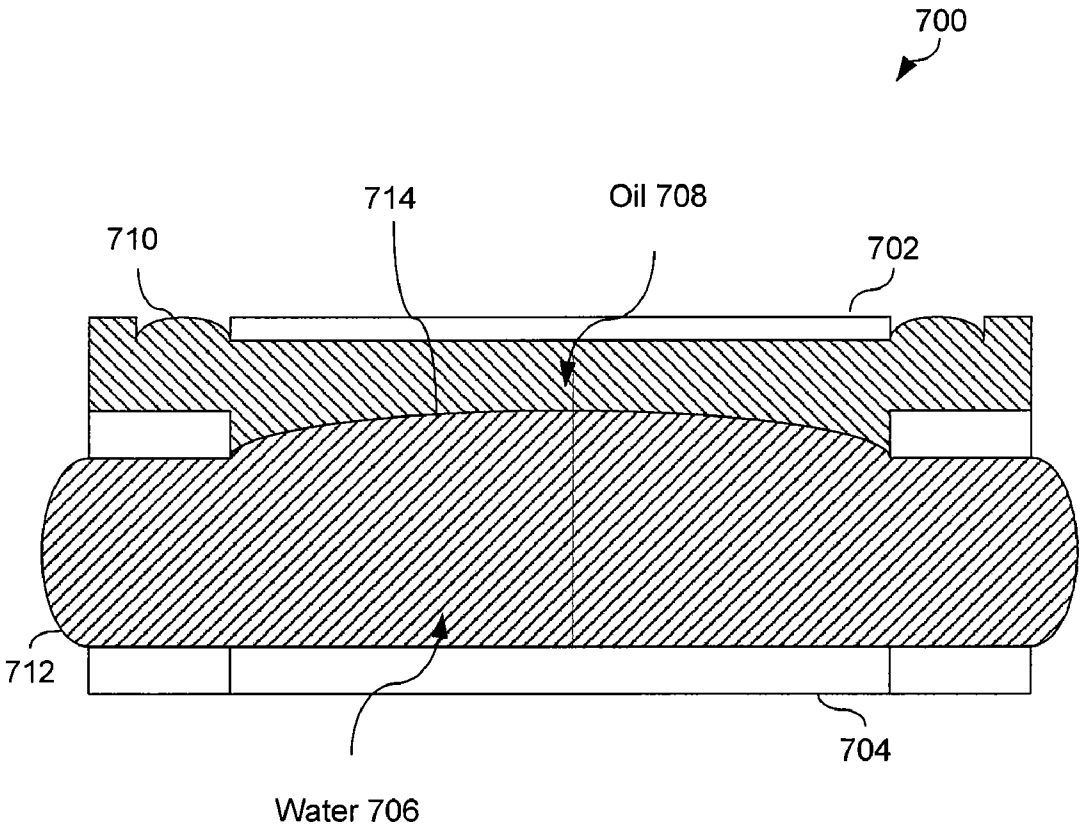


FIG. 7

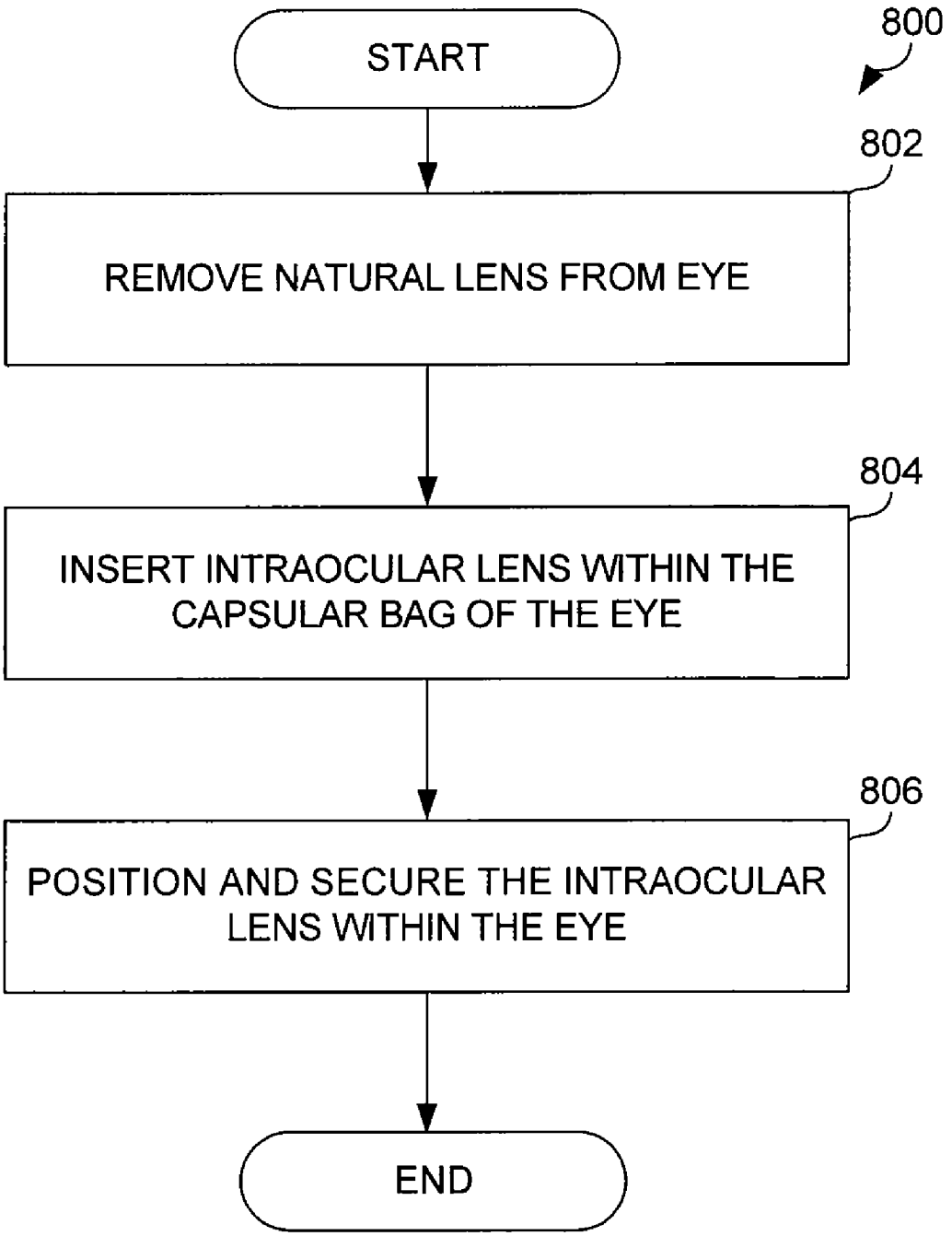

800
START
802
REMOVE NATURAL LENS FROM EYE
804
INSERT INTRAOCULAR LENS WITHIN THE CAPSULAR BAG OF THE EYE
806
POSITION AND SECURE THE INTRAOCULAR LENS WITHIN THE EYE
END

FIG. 8

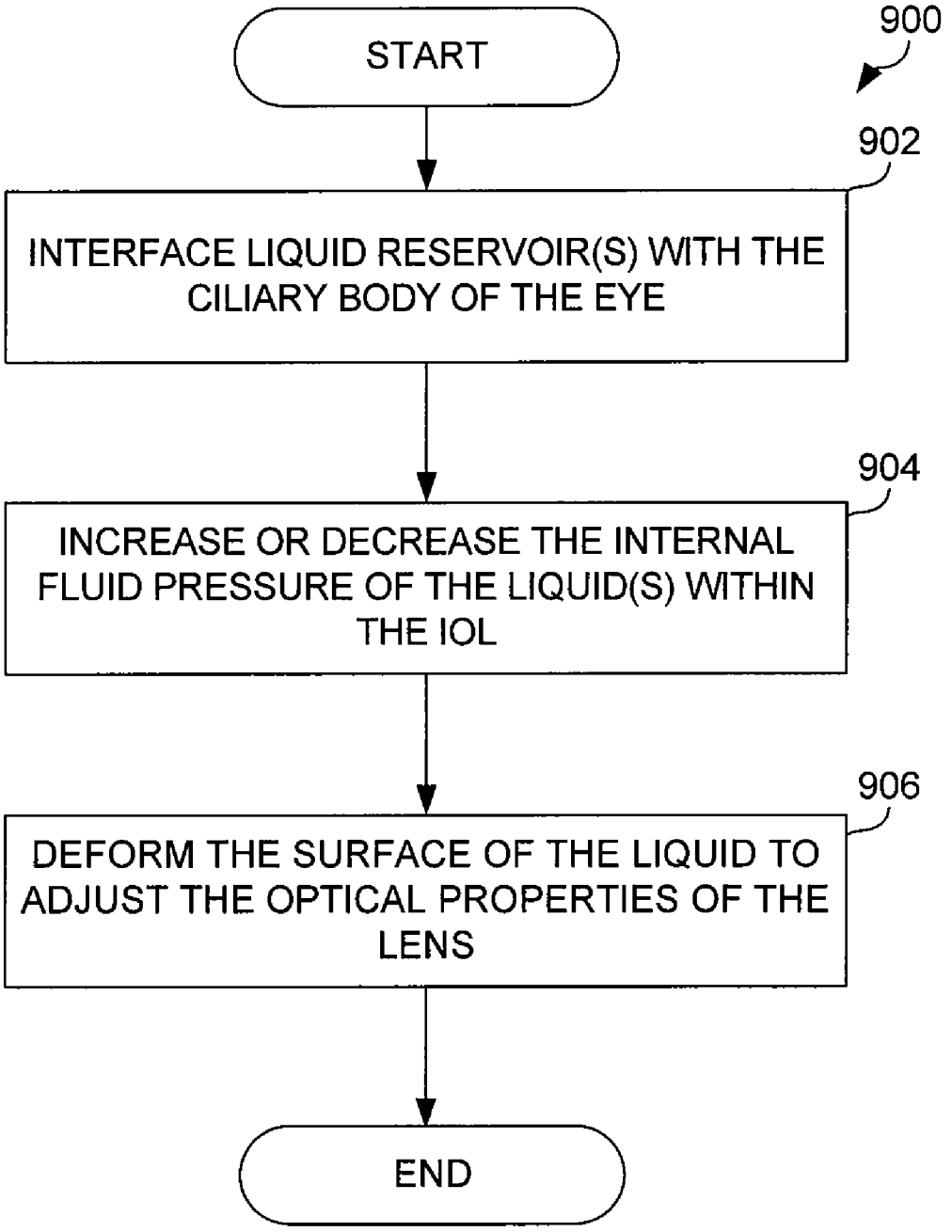

900
START
902
INTERFACE LIQUID RESERVOIR(S) WITH THE CILIARY BODY OF THE EYE
904
INCREASE OR DECREASE THE INTERNAL FLUID PRESSURE OF THE LIQUID(S) WITHIN THE IOL
906
DEFORM THE SURFACE OF THE LIQUID TO ADJUST THE OPTICAL PROPERTIES OF THE LENS
END

FIG. 9

ACCOMMODATING INTRAOCULAR LENS

[0001] This application claims priority to U.S. Provisional Application Ser. No. 61/105,517 filed on Oct. 15, 2008.

TECHNICAL FIELD OF THE INVENTION

[0002] The present invention relates generally to the human eye and more particularly to intraocular lenses (IOLs).

BACKGROUND OF THE INVENTION

[0003] The human eye in its simplest terms functions to provide vision by transmitting light through a clear outer portion called the cornea, and focusing the image by way of a lens onto a retina. The quality of the focused image depends on many factors including the size and shape of the eye, and the transparency of the cornea and lens. Age and/or disease often cause the lens to become less transparent. Thus, vision deteriorates because of the diminished light which can be transmitted to the retina. This deficiency in the lens of the eye is medically known as a cataract.

[0004] An accepted treatment for this condition is surgical removal of the lens and replacement of the lens function by Intraocular lenses (IOLs). IOLs are the artificial lenses that replace the eye's natural lens that is removed during cataract surgery. For many years most IOLs were made of poly (methylmethacrylate), a material with good optical characteristics and compatibility with the tissues of the eye. A disadvantage of PMMA is, however, that it is a very rigid material and the incision must be made large enough for implantation of the IOL. If the optical properties are not correctly matched, a need for a second IOL is required.

[0005] Traditional IOLs are monofocal, meaning these lenses offer vision at one distance only (far, intermediate or near). Traditional IOLs offer an improvement over the cataractous lens that is replaced during surgery, which provides only cloudy, blurred vision at any distance. But traditional IOLs mean that the patient must wear eyeglasses or contact lenses in order to read, use a computer or view objects at the unselected distance. There is still a need for multifocal and accommodating IOLs that offer the patient the possibility of seeing well at more than one distance, without glasses or contacts.

SUMMARY OF THE INVENTION

[0006] Embodiments of the present invention provide an improved ocular implant. This ocular implant includes an accommodating intraocular lens (IOL) and a number of haptics. The accommodating IOL includes a liquid suspended between two optically transparent plates or membranes to form a pressure lens that passes optical energy. The haptics mechanically couple to the IOL in order to position and secure the IOL within the eye. The IOL achieves accommodation by using the eye's ciliary muscles to vary the surface curvature of the liquid. The liquid may have a high surface tension and be surrounded by phobic liquid. Pressure from the ciliary muscles causes fluid to be added from or withdrawn to a reservoir. Increasing/decreasing the internal pressure of the liquid changes the angle (curvature) of the surface, thus changing the optical properties of the lens. When the pressure is released the liquid returns to the reservoir. The whole system may be sealed off from the interior of the eye by a membrane/transparent lens.

[0007] The ocular implant is operable to be implanted within a reduced sized incision of the capsular bag of an eye. This IOL includes a foldable optic and a number of haptics coupled to the optic. In one embodiment the haptics are multi hinged while another embodiment allows the haptics to be placed at an angle to the plane of the optic. The haptics flex while minimizing buckling and vaulting of the IOL in order to position and secure the IOL within the eye.

[0008] The IOL provided is made from a foldable optic. This allows the IOL to be implanted within a reduced sized incision. The haptics coupled to the IOL position the IOL within the capsular bag of an eye. The haptics may be multi hinged, oriented at an angle relative to the optic, or combination of the two. The optic may have an edge of less than about 0.15 millimeters.

[0009] Another embodiment of the present invention provides a method to correct the visual impairment of an aphakia. This method involves removal of a natural lens from an eye. An IOL is inserted during an incision in the capsular bag of the eye. As discussed previously, the IOL can accommodate both near and far vision. This is accomplished using a pressure lens that interfaces the IOL to the ciliary muscles of the eye. The haptics mechanically couple to the IOL in order to position and secure the IOL within the eye.

[0010] Other advantages of the present invention will become more apparent to one skilled in the art upon reading and understanding the detailed description of the preferred embodiments described herein with reference to the following drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] For a more complete understanding of the present invention and the advantages thereof, reference is now made to the following description taken in conjunction with the accompanying drawings in which like reference numerals indicate like features and wherein:

[0012] FIG. **1** illustrates the anatomy of the eye in which an IOL in accordance with embodiments of the present invention may be implanted;

[0013] FIG. **2** depicts an IOL in accordance with embodiments of the present invention;

[0014] FIGS. **3**A and **3**B provides a top down view and a cross section of IOL in accordance with embodiments of the present invention;

[0015] FIGS. **4**A and **4**B provide a top down view and a cross section of IOL in accordance with embodiments of the present invention;

[0016] FIGS. **5**A and **5**B provide a top down view and a cross section of IOL in accordance with embodiments of the present invention;

[0017] FIGS. **6**A and **6**B provide a cross section of IOL that depicts how the IOL may adjust using pressure from the ciliary muscles in accordance with embodiments of the present invention;

[0018] FIG. **7** provides a cross section of IOL that depicts how the IOL may adjust using pressure to adjust fluid pressure within the IOL to shape the IOL in accordance with embodiments of the present invention;

[0019] FIG. **8** provides a logic flow diagram of a method to correct for visual impairments such as aphakia of the eye in accordance with embodiments of the present invention; and

[0020] FIG. **9** provides a logic flow diagram of a method in which an IOL uses a pressure lens to accommodate for near and far distance in accordance with embodiments of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0021] Preferred embodiments of the present invention are illustrated in the FIGs., like numerals being used to refer to like and corresponding parts of the various drawings.

[0022] An improved design for an ocular implant is provided by embodiments of the present invention. This ocular implant includes an accommodating intraocular lens (IOL) and a number of haptics. The accommodating IOL includes a liquid suspended between two optically transparent plates or membranes where the IOL passes optical energy. The haptics mechanically couple to the IOL in order to position and secure the IOL within the eye. The IOL achieves accommodation by using the eye's ciliary muscles to vary the surface curvature of an amount (e.g., a drop) of the liquid. The liquid has a high surface tension and is surrounded by phobic liquid. Pressure from the ciliary muscles causes fluid from a reservoir to be added to or withdrawn from the drop. Increasing/decreasing the size of the drop changes the angle of the surface, thus changing the index of refraction. When the pressure is released, the liquid returns into the reservoir. The surrounding liquid is used to increase the stability of the suspended drop. The surrounding liquid can flow into and out of a second reservoir as the liquid droplet increased or decreased in size. The whole system can be sealed off from the interior of the eye by a membrane/transparent lens.

[0023] Sight is, by far, one of our most valuable senses. Without our vision, everyday tasks like driving and reading books would be impossible. Our eyes are complex machines that deliver a clear picture of the world around us—communicating the simplest of colors, shapes and textures. FIG. **1** illustrates the anatomy of the eye into which the improved design for ocular implant provided by the present invention may be placed. Eye **100** includes cornea **102**, iris **104**, pupil **106**, lens **108**, lens capsule **110**, zonules, ciliary body **120**, sclera **112**, vitreous gel **114**, retina **116**, macula, and optic nerve **120**. Cornea **102** is a clear, dome-shaped structure on the surface of the eye acts as a window, letting light into the eye. Iris **104** is the colored part of the eye, called the iris, is a muscle surrounding the pupil that relaxes and contracts to control the amount of light entering the eye. Pupil **106** is the round, central opening of the iris. Lens **108** is the structure inside the eye that, in combination with the cornea, operates to focus light on the retina. Lens capsule **110** is an elastic bag that envelops the lens, helping to control lens shape when the eye focuses on objects at different distances. Zonules are slender ligaments that attach the lens capsule to the inside of the eye, holding the lens in place. The Ciliary body is the muscular area attached to the lens that contracts and relaxes to control the size of the lens for focusing. Sclera **112** is the tough, outermost layer of the eye that maintains the shape of the eye. Vitreous gel **114** is the large, gel-filled section that is located towards the back of the eyeball, and which helps to maintain the curvature of the eye. Retina **116** is a light-sensitive nerve layer in the back of the eye that receives light and converts it into signals to send to the brain. The macula is the area in the back of the eye that contains functions for seeing fine detail. Optic nerve **118** connects and transmits signals from the eye to the brain.

[0024] Ciliary body **122** lies just behind the iris **104**. Attached to the ciliary body **122** are tiny fiber "guide wires" called zonules **124**. Lens **108** is suspended inside the eye by the zonular fibers **124**. Nourishment for the ciliary body **122** comes from blood vessels which also supply the iris **104**. One function of ciliary body **122** is to control accommodation by changing the shape of the lens **108**. When the ciliary body **122** contracts, the zonules **124** relax. This allows the lens **108** to thicken, increasing the eye's ability to focus up close. When looking at a distant object, ciliary body **122** relaxes, causing the zonules **124** to contract. The lens **108** then becomes thinner, adjusting the eye's focus for distance vision. Embodiments of the present invention provide an IOL that uses these functions of the ciliary body to control accommodation of the IOL by changing the shape of the IOL by changing the internal pressure of a fluid within the IOL lens.

[0025] FIG. **2** depicts an IOL **200**. IOL **200** is an artificial lens implanted in the eye to restore vision after a natural lens has been removed. The need for the IOL may be due to cataract, disease or accidents. The lens of the IOL may be convex on both sides (biconvex) and made of a soft plastic, such as the Acrysof material manufactured by Alcon Laboratories, Inc., of Fort Worth, Tex., that can be folded prior to insertion, allowing placement through an incision smaller than the optic diameter of the lens. After surgical insertion into the eye, the lens gently unfolds to restore vision. The supporting arms (haptics) **202** provide for proper positioning of the IOL within the eye.

[0026] IOL **200** may be positioned in the posterior chamber of the eye, replacing the natural lens. This position allows IOL **200** to correct the visual impairment of aphakia (absence of the natural lens). IOL **200** may have a biconvex optic that is shaped to provide increased depth of focus. IOL **200** can provide good near, intermediate and distance vision with increased independence from glasses in patients who have undergone cataract surgery. IOL **200** can deliver quality vision for various lighting situations. The central portion **204** may be a pressure lens whose shape may be changed by using the ciliary muscles to adjust the accommodation of the lens. Thus, IOL **200** can accommodate both near and distant focal points.

[0027] FIGS. **3**A and **3**B provide a top down view and a cross section of IOL **300** in accordance with embodiments of the present invention. IOL **300** provided is an artificial lens implanted in the eye to restore vision after a natural lens has been removed. IOL **300** is operable to be folded and delivered into the capsular bag through a sub 2.1 mm incision and is optically stable after implantation. The need for the IOL may be due to cataract, disease or accidents. In the relaxed position the lens of the IOL **300** may be convex on both sides (biconvex) and made of a soft plastic that can be folded prior to insertion, allowing placement through an incision smaller than the optic diameter of the lens. After surgical insertion into the eye, the lens gently unfolds to restore vision. The supporting arms (haptics) **302** provide for proper positioning of the IOL within the eye.

[0028] Initial alterations to prior IOLs that would allow for implantation through a reduced incision resulted IOLs that were non-optically stable after implantation. These prior attempts merely decreased the thickness of the optic and haptics. This created an unstable optic. Embodiments of the present invention provide unique features that result in an optically stable IOL in the compressed state. These features may be implemented in various combinations and include: (1)

a reduced nominal optic edge **308** less than about 0.15 mm; (2) angulated haptic/optic planes; (3) ensuring that any vaulting of optic **306** will occur posteriorly (it might be expected that the lens would vault in the anterior direction because of the angle of the haptics compared to the optic; however, the design actually creates an unexpected, non-vaulting lens; and (4) a multi (double) hinged haptic design. These features result in an optically sound and stable IOL when compressed to 10 mm or 9 mm, while maintaining acceptable force (3.0E-04 N) in the haptics.

[0029] IOL **300** may be positioned in the posterior chamber of the eye, replacing the natural lens. This position allows IOL **300** to correct the visual impairment of aphakia (absence of the natural lens). IOL **300** may have a biconvex optic. IOL **300** delivers quality vision for various lighting situations.

[0030] In brightly lit conditions, the central portion **304** sends light waves simultaneously to both near and distant focal points, while, in dimly lit conditions, the surrounding area **306** sends greater energy to distance vision.

[0031] Haptics **302** may be molded in a single piece from the same material as optics **304** and **306**. The material used to make IOL **300** may be any soft biocompatible material capable of being folded. Suitable materials are the hydrogel, silicone or acrylic materials described in U.S. Pat. Nos. 5,411,553 (Gerace, et al.), 5,403,901 (Namdaran, et al.), 5,359,021 (Weinschenk, III, et al.), 5,236,970 (Christ, et al.), 5,141,507 (Parekh) and 4,834,750 (Gupta). Optic **310** has an anterior side **314** and a posterior side **312** and may be of any suitable diameter, with between 4.5 mm and 7.0 mm being preferred and 5.5 mm being most preferred. Optic **310** may also be elliptical or oval. The initial thickness of optic **310** will vary depending on the dioptic power desired and the index of refraction for the material used, but generally will be between 0.4 mm and 1.5 mm. Further, the range of optic thickness will vary depending on the ability of the ciliary muscles to exert and relax pressure within the optic as will be discussed with reference to FIGS. **6**A, **6**B and **7**.

[0032] IOL **300** provides for a greater diameter of optic **310** while minimizing the size of the surgical incision. The material used to make optic **310** may be modified to absorb ultraviolet radiation, or any other desired radiation wavelength.

[0033] Embodiments of haptics **302** can contain gusset **316**, first elbow **318**, second elbow **324** and distal portion **320** having widened portion **322**. In one embodiment, the thickness of first elbow **318**, second elbow **324** and distal portion **320** of haptic **302** is uniform, and preferably between about 0.30 mm and 0.60 mm, with between about 0.40 mm and 0.50 mm being more preferred and about 0.43 being most preferred. Gusset **316**, however, has a thickness that is reduced toward anterior side **312** of optic **310**. Gusset **316** preferably is between about 0.15 mm and 0.60 mm thick, with between about 0.25 mm and 0.35 mm thick being more preferred and about 0.30 mm being most preferred. This reduced thickness generally extends from edge **308** of optic **310**. The relatively thin cross section of gusset **316** and edge **308** provides a thinner profile when IOL **300** is inserted through the surgical incision. The reduced thickness of gusset **316** also facilitates fluid circulation (e.g., viscoelastic) between posterior side **314** and anterior side **312** of IOL **300**. Alternatively, gusset **316** or optic **310** may be provided with other means (such as holes, grooves, notches, micro-fenestration, or protuberances (all not shown)) to facilitate fluid flow between posterior side **314** and anterior side **312** of IOL **300**. The relatively long length and radius of distal portion **320** provides greater contact with the capsular bag for better fixation when IOL **300** is implanted in the eye. First elbow **318** and second elbow **324** create hinges that allow haptic **302** to flex while minimizing buckling and vaulting of optic **310**. Widened portion **322** increases the stiffness of haptic **302** just past elbow **318**, thereby increasing the strength of haptic **302** at a critical stress point.

[0034] FIGS. **4**A and **4**B provide a top down view and a cross section of IOL **400** in accordance with embodiments of the present invention similar to that provided in FIGS. **3**A and **3**B. Haptics **402** contain gusset **416**, elbow **418** and distal portion **420** having widened portion **422**. In this embodiment the haptics are angulated relative to the plane of the optic. The angulated haptic/optic planes are not parallel. One embodiment angles these planes at about 2.2°. The orientation of these planes ensures that any vaulting of optic **410** will occur posteriorly. Certain embodiments result in a non-vaulting lens (when compressed to about, e.g., 10 mm).

[0035] The relatively long length and radius of distal portion **420** provides greater contact with the capsular bag for better fixation when IOL **400** is implanted in the eye. Elbow **418** creates a hinge allowing haptic **402** to flex while minimizing buckling and vaulting of optic **410**. Widened portion **422** increases the stiffness of haptic **402** just past elbow **418**, thereby increasing the strength of haptic **402** at a critical stress point.

[0036] Advantages of embodiments of the present invention provide for: (1) an IOL that can be folded and delivered into the capsular bag through a sub 2.1 mm incision; (2) a single-piece design that represents a significant reduction in IOL volume without sacrificing mechanical stability; and (3) an IOL that can be fabricated as one piece.

[0037] FIGS. **5**A and **5**B provides a top down view and a cross section of an IOL **500** in accordance with embodiments of the present invention incorporating elements provided in FIGS. **3**A, **3**B, **4**A and **4**B. Haptics **502** contain gusset **516**, first elbow **518**, second elbow **524** and distal portion **520** having widened portion **522**. In this embodiment the haptics are multi-hinged and angulated relative to the plane of the optic. The angulated haptic/optic planes are not parallel. One embodiment angles these planes at about 2.2°. The orientation of these planes ensures that any vaulting of optic **510** will occur posteriorly. Certain embodiments result in a non-vaulting lens (when compressed to about, e.g., 10 mm).

[0038] The relatively long length and radius of distal portion **520** provides greater contact with the capsular bag for better fixation when IOL **500** is implanted in the eye. First elbow **518** and second elbow **524** create hinges allowing haptic **502** to flex while minimizing buckling and vaulting of optic **510**. Widened portion **522** increases the stiffness of haptic **502** just past first elbow **518**, second elbow **524**, thereby increasing the strength of haptic **502** at a critical stress point.

[0039] FIGS. **6**A and **6**B provide a cross section of an IOL **600** that depicts how the IOL **600** may be adjusted using pressure from the ciliary muscles to alter the shape of the lens **612** in accordance with embodiments of the present invention. Lens **612** includes an upper plate or membrane **602** and lower plate or membrane **604**. These membranes should be optically transparent. Additionally, if a liquid with a high enough surface tension is used, the membranes can be the surface of the liquid. The lens **612** is filled with a liquid such as water or oil having appropriate optical characteristics that allow it to pass light with a desired refractive index. Reservoir

608 is shown at either end of the lens **612** and allows ciliary muscles **610** to control or accommodate the shape of the lens **612** by pushing and/or pulling on a diaphragm bounding the reservoir **608**. For example, as shown in FIG. **6**A, as the ciliary muscles **610** pull at reservoir **608**, fluid **606** may be pulled from the lens **612** causing the surfaces or membranes **602** and **604** to have a concave shape. FIG. **6**B depicts the same wherein the ciliary muscles **610** push on the reservoir diaphragm causing the fluid pressure within the lens **612** to increase making the lens **612** convex instead of concave. Other embodiments, instead of having an actual plate or membrane, may employ a high surface tension fluid, thus eliminating the need for such a membrane. The pressure lens provided by embodiments of the present invention allow a fluid suspended between plates or within a hole to be flexed as a diaphragm pushes or pulls fluid to or from the liquid between the plates or in the hole.

[0040] FIG. **7** provides a cross section of an IOL that depicts how fluid pressure can be used to shape the IOL in accordance with embodiments of the present invention. Accommodating pressure lens **700** includes an upper plate **702**, a base plate **704**, a first liquid **706**, a second liquid **708**, a first diaphragm **712** associated with the first liquid **706** and a second diaphragm **710** associated with the second liquid **708**. As discussed previously, ciliary muscles may exert pressure by either pushing or pulling on the diaphragms **710** and **712**. As the diaphragms are pushed or pulled the internal pressure of liquids **706** and **708** changes, causing the interface **714** between the two liquids to change. This causes a curvature of lens **700** at interface **714** between liquids **706** and **708** to change. In this manner, the ciliary muscles may be used to adjust (accommodate) the pressure lens provided at the interface **714** between the two liquids to allow for both near and far vision.

[0041] FIG. **8** provides a logic flow diagram of a method to correct for visual impairments such as aphakia of the eye. Operations **800** begin with the removal of a natural lens from an eye in Step **802**. The IOL, which may be a multi-focal or accommodating IOL, may then be inserted within the eye. The lenses of the IOL may be convex on both sides (biconvex) and made of a soft plastic that can be folded prior to insertion. This folding allows placement through a reduced-size incision wherein the incision is smaller than the optic diameter of the IOL. After surgical insertion into the eye in step **804**, the IOL may gently unfold to restore vision. In Step **806**, the IOL is positioned and secured within the eye. This may be done with the use of supporting arms (haptics) to provide for proper positioning of the IOL within the eye. Embodiments of the present invention may place or position the IOL in posterior chamber of the eye to replace the natural lens as shown in FIG. **1**. This position allows the IOL to correct visual impairments such as the absence of a natural lens. The lens itself may be a multi-focal IOL as discussed previously. This can provide patients good near, intermediate and distance vision, and thus provide independence from spectacles following surgery to remove their natural lens.

[0042] FIG. **9** provides a logic flow diagram of a method in which an IOL uses a pressure lens to accommodate to provide near and far vision in accordance with embodiments of the present invention. Operations **900** begin after the IOL has been implanted in the eye, wherein the IOL may have been placed within the capsular bag of the eye. The IOL has liquid reservoirs that interface with the ciliary body of the eye in Step **902**. The interface made in Step **902** allows the ciliary bodies to increase or decrease the internal fluid pressure of the liquids within the IOL based on the relaxation or contraction of the ciliary muscles in Step **904**. This change in pressure results in the deformation of the surface of the liquid in Step **906**. This deformation adjusts the curvature or optical properties of the lens. By increasing or decreasing the internal fluid pressure, the IOL may accommodate to provide both near and far distance vision.

[0043] Accommodating IOLs can be generally grouped into three classes: (1) dynamic single optic (limited range and image quality); (2) dynamic multioptic (sizing and long term reliability issues); and (3) shape changing optic (capsule coupling, reliable distance focus issues). The interaction of shape-changing IOLs with the lens capsule and ciliary body is of special interest. Embodiments may couple the capsule to the IOL to allow single-optic, multiple-optic and shape changing IOLs. This may be done using inherent protein adhesion and augmented with biointegration and supplementary adhesives. The IOL may be constructed using materials with high elasticity like that of the capsule. The IOL may also include a biomimetic scaffold that stimulates tissue integration for shape changing IOL applications. The biomimetic scaffold takes advantage of inherent protein adhesion mechanisms, cellular cues at the capsular interface. Substrate material and surface topography/morphology, chemistry, and biological factors can be tailored to interact with the capsular bag environment so as to stimulate long term cellular integration of the biomimetic scaffold with the lens capsule.

[0044] In summary, embodiments of the present invention provide an improved lens design for an ocular implant. This ocular implant includes an accommodating intraocular lens (IOL) and a number of haptics. Embodiments of the accommodating IOL can include a liquid suspended between two optically transparent plates or membranes to form a pressure lens that passes optical energy. The haptics mechanically couple to the IOL in order to position and secure the IOL within the eye. The IOL achieves accommodation by using the eye's ciliary muscles to vary the surface curvature of the liquid. The liquid may have a high surface tension and be surrounded by phobic liquid. Pressure from the ciliary muscles causes fluid to be added from or withdrawn to a reservoir. Increasing/decreasing the internal pressure of the liquid changes the angle (curvature) of the liquid (lens) surface, thus changing the optical properties of the lens. When the pressure is released the liquid returns to the reservoir. The whole system may be sealed off from the interior of the eye by a membrane/transparent lens.

[0045] As one of average skill in the art will appreciate, the term "substantially" or "approximately", as may be used herein, provides an industry-accepted tolerance to its corresponding term. Such an industry-accepted tolerance ranges from less than one percent to twenty percent and corresponds to, but is not limited to, component values, integrated circuit process variations, temperature variations, rise and fall times, and/or thermal noise. As one of average skill in the art will further appreciate, the term "operably coupled", as may be used herein, includes direct coupling and indirect coupling via another component, element, circuit, or module where, for indirect coupling, the intervening component, element, circuit, or module does not modify the information of a signal but may adjust its current level, voltage level, and/or power level. As one of average skill in the art will also appreciate, inferred coupling (i.e., where one element is coupled to another element by inference) includes direct and indirect

coupling between two elements in the same manner as "operably coupled". As one of average skill in the art will further appreciate, the term "compares favorably", as may be used herein, indicates that a comparison between two or more elements, items, signals, etc., provides a desired relationship. For example, when the desired relationship is that signal **1** has a greater magnitude than signal **2**, a favorable comparison may be achieved when the magnitude of signal **1** is greater than that of signal **2** or when the magnitude of signal **2** is less than that of signal **1**.

[0046] Although the present invention is described in detail, it should be understood that various changes, substitutions and alterations can be made hereto without departing from the spirit and scope of the invention as described by the appended claims.

What is claimed is:

1. An ocular implant, comprising:

an intraocular lens (IOL) operable to pass optical energy, the IOL comprising:

a first optical membrane;

a second optical membrane;

a liquid located between the first optical membrane and second optical membrane;

at least one liquid reservoir operable to add liquid to or withdraw liquid from the liquid located between the first optical membrane and second optical membrane;

a diaphragm that interfaces ciliary muscles of an eye to the at least one liquid reservoir, wherein the contraction or relaxation of the ciliary muscles forces the at least one reservoir to add liquid to or withdraw liquid from the liquid located between the first optical membrane and second optical membrane; and

a plurality haptics coupled to the IOL operable to position the IOL within an eye.

2. The ocular implant of claim **1**, wherein the liquid comprises a high surface tension liquid surrounded by phobic liquid.

3. The ocular implant of claim **1**, wherein the contraction or relaxation of the ciliary muscles changes an internal pressure of the liquid located between the first optical membrane and second optical membrane, the internal pressure affecting the curvature of the first optical membrane and the second optical membrane.

4. The ocular implant of claim **1**, further comprising a membrane/transparent lens operable to isolate the ocular implant from the interior of the eye.

5. The ocular implant of claim **1**, wherein the haptics are angled at about 2.2° to the plane of the IOL.

6. The ocular implant of claim **1**, wherein the IOL is operable to replace a natural lens of the eye.

7. The ocular implant of claim **1** operable to be implanted within a sub 2.1 mm incision.

8. The ocular implant of claim **1**, wherein the IOL comprises a biconvex optic.

9. An ocular implant, comprising:

an intraocular lens (IOL) operable to pass optical energy, the IOL comprising:

a high surface tension liquid;

a phobic liquid surrounding the high surface tension liquid;

at least one liquid reservoir operable to add or withdraw high surface tension liquid;

a first diaphragm that interfaces ciliary muscles of an eye to the at least one liquid reservoir, wherein the contraction or relaxation of the ciliary muscles force the at least one liquid reservoir to add or withdraw high surface tension liquid; and

a plurality haptics coupled to the IOL operable to position the IOL within an eye.

10. The ocular implant of claim **9**, wherein the contraction or relaxation of the ciliary muscles changes an internal pressure of the high surface tension liquid, the internal pressure affecting the curvature of an optical surface of the high surface tension liquid.

11. The ocular implant of claim **9**, further comprising a membrane/transparent lens operable to isolate the ocular implant from the interior of the eye.

12. The ocular implant of claim **9**, further comprising:

at least one additional liquid reservoir operable to add or withdraw phobic liquid;

a second diaphragm that interfaces ciliary muscles of an eye to the at least one additional liquid reservoir, wherein the contraction or relaxation of the ciliary muscles force the at least one additional liquid reservoir to add or withdraw phobic liquid.

13. The ocular implant of claim **12**, wherein the contraction or relaxation of the ciliary muscles changes a differential pressure between the high surface tension liquid and the phobic liquid, the differential pressure affecting the curvature of an interface between the high surface tension liquid and the phobic liquid.

14. The ocular implant of claim **9**, wherein the IOL is operable to replace a natural lens of the eye.

15. The ocular implant of claim **9**, wherein the IOL comprises a biconvex optic.

16. A method to correct visual impairment of aphakia comprising:

removing a natural lens from an eye;

inserting an intraocular lens (IOL) through an incision of a capsular bag of the eye, the IOL, the IOL comprises:

a first optical membrane;

a second optical membrane;

a liquid located between the first optical membrane and second optical membrane;

at least one liquid reservoir operable to add liquid to or withdraw liquid from the liquid located between the first optical membrane and second optical membrane;

a diaphragm operable to interface ciliary muscles of the eye to the at least one liquid reservoir, wherein the contraction or relaxation of the ciliary muscles force the at least one liquid reservoir to add liquid to or withdraw liquid from the liquid located between the first optical membrane and second optical membrane; and

a plurality haptics coupled to the IOL operable to position the IOL within an eye;

positioning and securing the IOL within the eye with the plurality of haptics coupled to the IOL; and

interfacing the ciliary muscles of the diaphragm of the IOL.

17. The method of claim **16**, wherein the liquid comprises a high surface tension liquid.

18. The method of claim **16**, wherein the contraction or relaxation of the ciliary muscles changes an internal pressure of the liquid located between the first optical membrane and second optical membrane, the internal pressure affecting the curvature of the first optical membrane and the second optical membrane.

19. The method of claim **16**, further comprising isolating the ocular implant from the interior of the eye with a membrane/transparent lens.

20. The method of claim **16**, wherein the IOL is operable to replace a natural lens of the eye.

21. The method of claim **16**, wherein the IOL comprises a biconvex optic.

22. A method to correct visual impairment of aphakia comprising:

removing a natural lens from an eye;

inserting an intraocular lens (IOL) through an incision of a capsular bag of the eye, the IOL, the IOL comprises:

a high surface tension liquid;

a phobic liquid surrounding the high surface tension liquid;

at least one liquid reservoir operable to add or withdraw high surface tension liquid;

a first diaphragm that interfaces ciliary muscles of an eye to the at least one liquid reservoir, wherein the contraction or relaxation of the ciliary muscles force the at least one liquid reservoir to add or withdraw high surface tension liquid; and

a plurality haptics coupled to the IOL operable to position the IOL within an eye;

positioning and securing the IOL within the eye with the plurality of haptics coupled to the IOL; and

interfacing the ciliary muscles of the diaphragm of the IOL.

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